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Why do we not pick the low-hanging fruit? Governing adaptation to climate change and resilience in Tyrolean mountain agriculture

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ABSTRACT

Impacts of climate change have become more and more evident and can be observed in ecosystems, societies and economies worldwide. Mountain agriculture is especially vulnerable to climate change, and adaptation seems crucial. Thus, certain adaptation activities, such as installing irrigation technology, switching to drought-resistant crop varieties or shifting planting dates, can already be observed. Despite these efforts, the barriers for climate change adaptation are still manifold and lead to adaptation gaps. One problem is that many approaches ignore non-climatic drivers, such as economic conditions or cultural aspects, which have a strong influence on farmers´ decisions. In the literature, the focus is mostly on planned, "top-down" induced adaptations, where climate change is considered the most important driver. Within this study, we focus on local, "bottom-up" adaptation actions in Tyrolean mountain agriculture that may be triggered by climatic as well as by non-climatic drivers. We identify 27 adaptation practices and cluster them into six types of climate change adaptation: ´Resilience-raising products and production´, ´Hidden actions by farmer organizations´, ´CC motivated agronomic actions´, ´CCA scientific knowledge production´, ´Risk-driven adaptations´ and ´Hidden governmental actions´. These types are helpful to show the broad range of local practices contributing to climate change adaptation. Several adaptation actions from practice are not motivated by climate change and thus are termed "hidden" adaptations, as they do not fit into common adaptation concepts. Hidden climate change adaptation practices, although not considered to date in official CCA policy documents, constitute "low-hanging fruit" for decision makers as they have already proved their feasibility and gained legitimacy by actors on the ground. We argue that additional support for such hidden adaptation practices can help to overcome present adaptation barriers and adaptation gaps.

1. Introduction

The availability and productivity of agriculturalland is particularly exposed to climate variability and affected by climate change (Lobell et al., 2008; Vermeulen et al., 2012). The structure of the current food system is extremely fragile, and food security in affluent regions can no longer be taken for granted (IPCC, 2014a; Candel, 2014). In addition, people in countries of the Global North increasingly recognize their global responsibility regarding consumer and dietary behaviors (de Boer et al., 2016) and their vulnerability to impacts from disruptions of food trade and rising prices for production input supplies (Van der Ploeg, 2010). Hence, as a leading consumer of fossil fuels and a large contributor to GHG emissions, the agriculture and food sector has an important role to play in climate change mitigation and adaptation (McMichael, 2011).

At least since the negotiations of the Kyoto Protocol, climate change has been perceived as a global threat and a major future challenge by science (Perry, 2015) as well as by the public (Moser and Dilling, 2004). The media presence increases considerably with the release of IPCC reports or international climate conferences, such as the very prominent UNFCCC COP 21 2015 in Paris with its agreement on the 'two degrees' goal. There is a growing consensus that, in addition to mitigation, adaptation to climate change is imperative (Adger et al., 2009; Berrang-Ford et al., 2011; Rickards and Howden, 2012). Political commitment

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to climate change adaptation (CCA) is expressed at multiple levels. Since the millennium the world of states under the UNFCCC umbrella declared and established the concept of adaptation next to mitigation as a second very important pillar of any climate policy, and the Cancun Adaptation Framework (2010) called for further national adaptation planning. In April 2013, the EU adopted an Adaptation Strategy (EC, 2013), followed by several National Adaptation Strategies by EU member states. Hence, there is a strong need to implement various adaptive practices – understood as a "*process of adjustment to actual or expected*" (IPCC, 2014b:118) climate change effects – and measures that increase resilience ("*the capacity of social, economic and environmental systems to cope with a hazardous event[s]*") (IPCC, 2014b:127) or adaptive capacities ("*the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences*") (IPCC, 2014b:118).

Despite this broad political commitment, barriers for implementing CCA are still manifold, especially on a local level (Adger et al., 2007; Dow et al., 2013; Ford and King, 2015; Klein et al., 2014; Moser et al., 2010). National strategies cannot be easily transferred to the local level by top-down processes. The problem-solving capacity is critically determined by concrete local actions (Tompkins et al., 2010; Smit and Wandel, 2006), and its effectiveness depends on institutionalized local networks that are locally knowledgeable and locally responsive (Campos et al., 2014). The resulting difference between stated adaptation needs and existing adaptation efforts has become known as the "adaptation gap" (Chen et al., 2016). To overcome barriers and thresholds and to avoid maladaptation, a better understanding of adaptation processes is needed that allows interventions *"at the most appropriate scales"* (Adger, 2001:921).

For a better understanding and well-targeted support of CCA, it is helpful to differentiate among different types of adaptations. Differentiation receives much attention in the literature (Biagini et al., 2014; Eakin et al., 2014; Smit et al., 2000), and spontaneous vs. planned as well as reactive vs. anticipatory adaptations are the most common types (Fankhauser et al., 1999; Füssel, 2007; Malik et al., 2010). Smit and Skinner (2002) have developed a typology of adaptation options in agriculture considering two dimensions: scale and stakeholders. Another typology can be found in Tompkins et al. (2010): eight main types represent adaptation outputs, namely, research, planning, networking, awareness raising, training and advocacy, legislation and implementing adaptation. Altogether, the literature focuses strongly on theoretical adaptation, while only a few studies have examined actual CCA practices (Berrang-Ford et al., 2011; Chen et al., 2016; Tompkins et al., 2010).

This paper draws attention to actual adaptation actions and policies on a local scale, and thus does not include CCA on a national and EU level. It investigates a specific vulnerable land use system – mountain agriculture in Tyrol (Austria). Mountain agriculture is affected by various climate change impacts and effects and particularly requires adaptation strategies to exploit opportunities and avert potential loss (Poetsch et al., 2014). Farmers act in a very complex field with various challenges (Mitter et al., 2015), and decisions are made in response to political, economic, institutional, and biophysical conditions (Risbey et al., 1999; Wandel and Smit, 2000; Campos et al., 2014). Hence, climate change often plays only a minor role as a trigger for actions in farmers´ daily lives (Tompkins et al., 2010, Berrang-Ford 2011). Therefore, our approach focuses on local every-day adaptation practices and the driving forces and motives behind them. Resilience plays a central role within our approach as it leads to better adapted (agricultural) systems (Adger et al., 2005). We show the full spectrum of already implemented adaptation practices in the mountain agriculture sector of Tyrol. Based on a cluster analysis, a CCA characterization is introduced, and different adaptation types are identified. We compare the identified CCA practices with the Tyrolean climate strategy to identify further adaptation needs. With this practical orientation and integrated perspective, we wish to show the diversity of local adaptation practices and to identify low-hanging fruit for policy and decisions makers.

In the following section, we critically assess the effects of top-down CCA policies; then, we follow with a description of mountain agriculture in Tyrol. Subsequently, we describe the methods used and present the dimensions chosen for differentiation between CCA types. Based on these dimensions, we introduce our CCA typology for Tyrolean mountain agriculture. By contrasting this typology with action fields from the Tyrolean climate strategy we identify adaptation gaps. Finally, we end with a discussion of our results and conclusions.

2. Critical assessment of the effects of climate change adaptation policies

The scientific debate about the effectiveness of CCA policies is comprehensive (cf. Bauer et al., 2012; Casado-Asensio and Steurer, 2014). It essentially refers to the question of whether it is enough to rely on international and national CCA policies implemented top-down at the local scale or whether there is a need for complementary bottom-up measures. Since the publication of the European Commission's Green and White Papers (EC, 2007, 2009), many EU countries have adopted national strategies to bring adaptation to the national policy agenda and to mainstream adaptation, which means to facilitate the integration and coordination of climate change adaptation policies with other public policy fields and related funding streams. In Austria, as in other EU member states, the national adaptation strategy was approved by the federal government in 2012 (Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2013).

In sum, all of these top-down adaptation policies are planned, and the related measures can be either reactive or anticipatory (Smit et al., 2000; Smit and Wandel, 2006). However, government-driven top-down approaches have limits in stimulating concrete local adaptation practices (for the UK, see Tompkins et al., 2010). Many reasons could be advanced to explain such a gap. Local actors, for example, are simply not aware of CCA policies (Grüneis et al., 2016); their behavior is motivated instead by different non-climate related stimuli such as cost savings, social pressure or individual risk perceptions (Adger et al., 2005; Grothmann and Patt, 2005), or the CCA governance at lower scales "*is hampered by the autonomy enjoyed by the municipalities*" (Juhola et al., 2011:244).

The discourse on "second generation" adaptation (Burton et al., 2002; Moser and Boykoff, 2013; Boyd and Cornforth, 2013) takes more account of local contexts and pluralistic drivers of adaptation. In contrast to first generation adaptations, which aim at "planned" adaptation solutions to particular CC problems (Boyd and Cornforth, 2013; Kates et al., 2012; Moser, 2009), second generation adaptations also consider environmental, social, political and economic factors (Grasso, 2009). They address the context in which hazards occur (Burton et al., 2002) and contribute to increased systems resilience.

Practices that increase the adaptive capacity may occur at the local level without being triggered by any national or sub-national adaptation policy or by the issue of climate change at all. These non-climatic conditioned efforts must be considered if we are interested in grasping the whole picture of adaptation, as argued by Tompkins et al. (2010) or the literature on community-based adaptation which emphasizes the social, political, and economic drivers of vulnerability (Ayers and Forsyth, 2009; Forsyth, 2013). In order to integrate and simplify all these different concepts and adaptation practices, Grüneis et al. (2016) suggest a framework that distinguishes three types of CCA according to their climate-related motivations: explicit adaptations, multi-purpose adaptations, and hidden adaptations. Explicit adaptations are directly and solely motivated by climate change, whereas hidden adaptations are motivated only by non-CC drivers, such as agricultural policies, markets, or lifestyle changes. Multi-purpose adaptations represent a hybrid form, where CC is one driver among other non-climatic drivers.

Hence, in this paper, we extend the common definition of climate

adaptation policies from top-down actions by governments including legislation, regulations and incentives (Burton et al., 2002) to a broader conceptual thinking that includes all strategies and measures, which – purposefully planned or not – enhance the adaptive capacities to climate change. Such an integrative strategy also requires a new approach for empirical research. To date, the "*anatomy of adaptation*" has been assessed asking "*three questions: (i) adapt to what? (ii) who or what adapts? and (iii) how does adaptation occur?*" (Smit et al., 2000:224). The most important question is whether the adaptation activities or processes are directly linked to climate change effects and related vulnerabilities (adapt to what?), but such an approach underestimates the capacities of farmers to find their own (autonomous) solutions to their problems. Locals have collected many experiences and problem-solving abilities regarding how to react to common threats linked to climate variability and other socio-economic or environmental changes in the past (Berkes and Jolly, 2001; Finan and Nelson, 2001; Jennings, 2009; Naess, 2013). From this perspective, the ability to adapt depends to a large extent on existing local knowledge, needs, motives and behaviors, which govern daily life and are decisive for real-world decision-making processes in agriculture.

Within this paper, we are not proposing that top-down adaptation policies are unimportant, but we show that many practices and measures that increase resilience or adaptive capacities at the local level occur irrespective of a direct CCA policy supporting or promoting them. We present every-day practices and the driving forces and motives behind them based on the case study of Tyrolean agriculture. The aim of this research is to identify practices, independent of the motivation behind, which have the potential to act as CCA-actions and thus merit further attention and support.

3. Case study – mountain agriculture in Tyrol

3.1. Case study selection

The extraordinarily high increase in temperature within the European Alps – twice as large as the northern-hemispheric average from 1900 to 2000 (Auer et al., 2007) – shows that Alpine regions are among the most vulnerable regions to climate change worldwide. As the region of Tyrol lies in the middle of the European Alps (see Fig. 1), we consider it as a good case study area for local climate change adaptation practices. The federal state of Tyrol in Austria, which is located in the middle of the European Alps with mountains up to 3,798 m above sea level, can be considered as representative for many European mountain regions dominated by dairy production. The next sections give an overview on the expected climate change effects for Tyrolean agriculture, the local pressures and main policies addressing CCA.

3.2. Effects of climate change on Tyrolean agriculture

Tyrolean mountain agriculture is particularly affected by climate change as agricultural production depends directly on climatic conditions (Lobell et al., 2008; Vasconcelos et al., 2013; Vermeulen et al., 2012) and as mountain regions are especially exposed to climate-related changes (Beniston, 2010; Diaz et al., 2003). The particularly high temperature rise within the European Alps (Brunetti et al., 2009) may favor the spread of harmful organisms or invasive weeds (Auer et al., 2007). Higher temperatures may also become problematic for livestock, reduce productivity and increase the risk for diseases (APCC, 2014; IPCC, 2014a). Summers with low precipitation may lead to drought damages in grasslands - the main land use type in Tyrol (APCC, 2014). However, Tyrolean mountain agriculture may also benefit from a temperature rise as total productivity in grasslands is projected to increase (Mitter et al., 2015). Next, to incremental changes, extreme events can lead to dramatic damages through erosion, harvest shortfalls or damage to farm buildings and infrastructure, but they are hardly predictable due to the high degree of uncertainty (APCC, 2014). Global effects of climate change may also affect Tyrol´s agriculture, which depends on global markets for production inputs and food trade (IPCC, 2014a). Climate change, however, is only one of several challenges Tyrolean mountain farmers must cope with.

3.3. Dominant pressures in Tyrolean agriculture

Tyrolean agriculture is dominated by family farms, and two-thirds are run by part-time farmers. Most farms focus on dairy production and livestock breeding on permanent grassland. However in the valleys, arable farming and vegetable and fruit production are also present. Small-scale agriculture in Alpine regions is under enormous pressure (Schermer and Kirchengast, 2006), and farmers often perceive the mountain environment as a natural handicap (Delay et al., 2015). Furthermore, farmers' decisions are embedded in complex and changing political, economic, institutional, and biophysical conditions (Bradshaw et al., 2004; Kandlikar and Risbey, 2000; Wandel and Smit, 2000). As competition on mass markets is virtually impossible, Tyrolean farmers are forced to go for quality production, offering additional services, often related to tourism and off farm employment. Tourism is one of the most important sources of income in the region of Tyrol. The active participation in tourism-related activities is an important economic backbone of farm resilience (Rieder et al., 2009). Agriculture also plays an important role in sustaining the cultural landscape, which characterizes the region and is important for tourism, biodiversity and local identity (Schermer and Kirchengast, 2006).

3.4. Agricultural policy in Tyrol

Austrian agricultural policy has addressed the constraints and pressures of mountain farming and supported diversification and environmental sound agricultural practices already since the 1980s (Schermer, 2015). Especially since Austria's accession to the EU in 1995, the agri-environmental program ÖPUL has become the overarching policy instrument within the rural development policy that also addresses climate change mitigation and adaptation. In contrast to the general orientation and interpretation of the Common Agricultural Policy (CAP) within EU countries, Austria favors rural development (the so called 2nd pillar of the CAP) over market incentives (1st pillar). The ÖPUL affects CCA both explicitly and implicitly as it was *"intended to foster the environmentally sound management of the agricultural areas in Austria"* with a *"broad spectre of measures"* (Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2016:11). Moreover, the Tyrolean government – like some of the other nine federal states of Austria - has passed a climate change and adaptation strategy on the federal level in 2015 (Amt der Tiroler Landesregierung, 2015). This strategy provides concrete measures in the fields of climate change mitigation and adaptation for 12 sectors, including agriculture (Amt der Tiroler Landesregierung, 2015). All measures for the agricultural sector are listed in Section 5.2.

4. Methods

To build a typology of local CCA actions, we followed a three-step approach: initially, we conducted interviews to identify CCA actions present in Tyrolean agriculture. In an iterative deductive-inductive process, we identified dimensions composed of different categories that differentiate these CCA actions identified. Finally, in a cluster analysis, we grouped the identified CCA actions into six types.

4.1. Identifying stakeholder perception of farmers' practices related to CCA

Whereas centrally planned explicit CCA measures can be identified from official CCA strategies, second generation CCA activities are neither confined to climate policies neither are they are explicitly referred

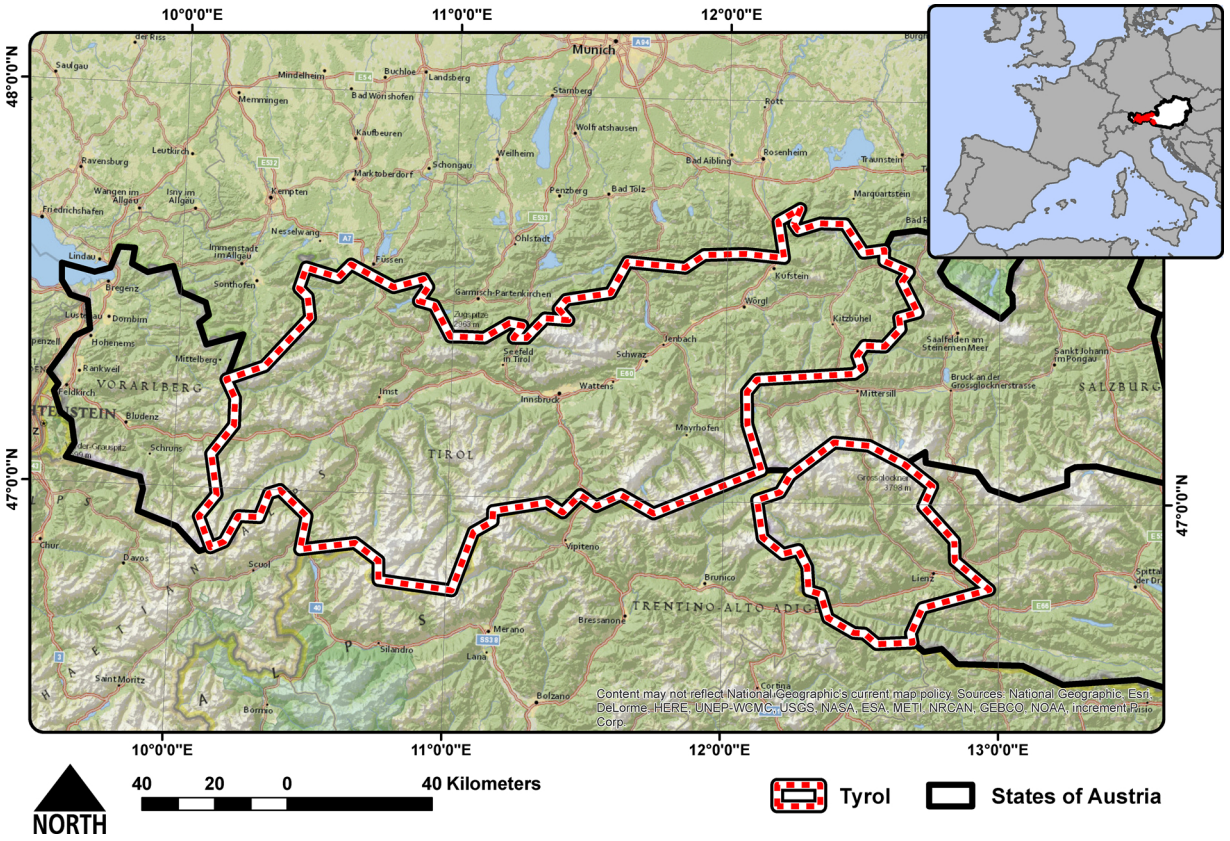

Fig. 1. The Austrian federal state Tyrol.

to as CCA activities. Therefore, more explorative approaches are needed that relate to local sectoral expert knowledge. Between June 2014 and June 2015, 20 semi-structured interviews were conducted to identify CCA practices in Tyrolean agriculture. The selection of interview partners focused on representatives from core agricultural sector organizations, such as the Chamber of Agriculture, the Austrian Federal State of Tyrol, the Association of Farm Women, the Association of Organic Farmers, the main agricultural insurance company ("Hagelversicherung") and the Federal Institute for Less Favored and Mountainous Areas.

The guidelines for the semi-structured interviews included three thematic areas. After an introductory question to build up trust, we asked the interviewees to recall local initiatives, programs and actions relevant to mountain farm's adaptation to climate change. This question aimed at identifying local, already implemented actions. Furthermore, the interviewees were asked about recent challenges and general developments in agriculture to supplement our understanding of agricultural stakeholder´s attitudes and perceptions of climate change among other pressures. All interviews were recorded and transcribed. Using qualitative content analysis, we identified a total of 29 local actions related to CCA (see also Grüneis et al., 2016). For this identification process, we coded actions that a) are taken in response to climatic stimuli (Smit et al., 2000), b) can increase climate resilience (Adger et al., 2005) or c) can reduce climatic vulnerabilities (Noble et al., 2014). As we asked for actions on the local level, neither the National Adaptation Strategy nor the national ÖPUL program were mentioned during our interviews. We excluded the Tyrolean climate strategy, as we would compare the local adaptation practices to this official climate policy in a next step. We also excluded ´hail nets´ from our list, since there is no scientific evidence between an increase in hailstorms and climate change (APCC, 2014). This exclusions lead to totally 27 remaining CCA actions. Our list of CCA actions is exemplary and not intended to be exhaustive. We did only list CCA actions which were mentioned by our interview partners. In the appendix we provide a table with descriptions of all CCA actions (Appendix 3). The results of the interviews were supplemented with data from desktop research to gain further understanding of the identified CCA actions.

4.2. Building dimensions for characterization

In the next step, we categorized the identified actions in a deductive-inductive iterative process. The goal was to select dimensions that did not overlap and were exhaustive. Furthermore, the dimensions had to be relevant for the real-life actions, identified in the interviews. Since the context relevance was of primary importance, the set of categories, deducted from literature, was adapted and complemented inductively (see the description of dimensions below).

There are many adaptation categorizations, which have been reviewed by Smit et al. (2000) or Biagini et al. (2014). Smit et al. (2000) identified five main areas for typification of adaptations: 1. timing relative to stimulus, 2. intent, 3. spatial scope, 4. form and 5. degree of necessary change. In our set of empirically identified CCA actions, we identified the areas 2, 3 and 4 and adapted them slightly for our empirical analysis. Furthermore, four additional dimensions supplemented the framework for a comprehensive investigation of CCA practices in Tyrol's mountain agriculture: actors, motivation, degree of formalization and adaptation output (Berrang-Ford et al., 2011; Cutter et al., 2008; Smit et al., 2000; Tompkins et al., 2010). Finally, we derived 37 categories from the transcripts that specified the seven dimensions presented in Table 1. This framework allowed a qualitative investigation on CCA adaptation practices in Tyrolean mountain agriculture.

Each CCA action is assigned to one category in each of the seven dimensions, except the dimension ´motivations´. Within this dimension some CCA actions are assigned to one or more motivations (e.g. awareness raising and ecological improvement), if several reasons motivated this action. The dimensions underlying the CCA types are

Table 1
Selected adaptation differentiation dimensions and categories.

Dimensions	Categories						
1. Actors	Govern ment	Farmers	Farmer organi zations	Market actors	Research institutions	Insurance companies	
2. Motivation	CCA	Productivity gain	Support for farmers	Aware ness raising	Env./ecol. improve-ment	Resilience raising	Cultural heritage conservation
3. CCA significance	Explicit CCA	Multi- purpose CCA	Hidden CCA				
4. Focus of intervention	Agro nomy	Mode of production	Awareness building	Research	Marketing	Risk manage ment	Social learning and support
5. Degree of formalization	High	Medium	Low				
6. Adaptation output	Adapted farm practices	Raised resilience	Climate Strategy	Raised aware ness	Knowledge production	Risk mitigation	
7. Spatial scale	Field	Farm	Region	Inter-regional			

described in more detail in the following paragraphs. We provide the characterization of all Tyrolean CCA actions in the appendix (Appendix 1).

4.2.1. Actors

Actors and their knowledge, attitudes, strategies, power, etc., play an important role for initiating and shaping CCA. They receive much attention from scientific scholars since they are initiators and/or implementers and strongly influence adaptation processes (Füssel, 2007; Geels and Schot, 2007, Pelling, 2011, Tompkins et al., 2010). European governments were not mentioned by the interviewees as we asked about practices in Tyrol by Tyrol's actors. Nevertheless, the EU is co-financer of some identified actions (e.g. farm women´s network), mainly through the Common Agricultural Policy. Inductively, we identify the following actors who seem to play roles in CCA in Tyrolean mountain farming: local government (of Tyrol), farmers, farmer organizations, market actors, research, institutions and insurance companies.

4.2.2. Motivation

Motivation indicates the reason for action, and non-climatic reasons also play important roles in initiating CCA (Wolf, 2011). Despite little overlaps between the categories (awareness raising – awareness building), consideration of motivation seems essential as it aims at the intention of an action which has a strong influence on the implementation of adaptations. Discerning the real motivation may be challenging, but it is decisive for effective adaptations (Tompkins et al., 2010). There are, for example, initiatives supporting farmers and ensuring the viability of farming in disadvantaged mountain areas (Darnhofer, 2015), which can contribute to better adapted farming systems. Smit et al. (2000) and Cutter et al. (2008) have focused on the drivers of action, which is a very similar approach. Inductively from the material, we derive the following motivations: adaptation to climate change, productivity gain, support for farmers, awareness raising, environmental/ecologic improvement, increasing resilience, and conservation of cultural heritage.

4.2.3. CCA significance

We differentiate three categories of CCA significance based on intent, the first being explicit adaptations made consciously in response to climate change and mainly planned, such as in most governmental climate strategies. Within multi-purpose CCA, several drivers are considered including climate change. However, CCA actions may also occur incidentally when non-climatic drivers are decisive, and then they are referred to as hidden adaptations as they are not obvious CCA actions (Grüneis et al., 2016; Tompkins et al., 2010).

4.2.4. Focus of intervention

Activities may be further distinguished according to their focus of intervention (Biagini et al., 2014). Such a differentiation is very sector-specific while some categories, such as risk management or awareness raising, may be suitable for all sectors (Smit and Skinner, 2002). Based on our material, we differentiate agronomy, mode of production, awareness building, research, marketing, risk management, and social learning and support.

4.2.5. Degree of formalization

A high degree of formalization implies limited flexibility and highly standardized activities, which are characterized by high coordination (Smith et al., 2005). Activities with a lower degree of formalization are less standardized or institutionalized (e.g., via documentation or rules) but are more flexible. Along this gradient, we distinguish between high, medium and low formalization.

4.2.6. Adaptation output

The CCA output refers to the CC-relevant outcome at the end of the adaptation process (Tompkins et al., 2010). We differentiate among adapted farm practices, improved resilience, adaptation strategy, raised awareness, production of scientific knowledge and risk mitigation.

4.2.7. Spatial scale

We also differentiate among four spatial scales (field, farm, region, and interregional) (Carter et al., 1994; Smithers and Smit, 1997). As this article focuses on sub-national climate change practices, national and global scales are not considered.

4.3. Clustering CCA actions and building a local CCA typology

Within the third step, we clustered the identified 27 CCA actions using the seven (nominal) dimensions as presented above (cf. Table 1). These seven dimensions were used in a (binary) cluster analysis to identify groups of similar CCA actions (Everitt, 2011). This approach leads to groups ("clusters") of CCA actions, which consist of actions that are more similar to each other than to those in other groups. A table with the characterization of all CCA actions as well as a detailed description of the cluster analysis are provided in the appendix (Appendix 1 and 2).

Each of the seven dimensions (see Table 1) were binary coded and fed in a hierarchical cluster analysis (for details see Appendix 2). Since each of these seven dimensions can be represented by a number of asymmetric binary values, the Jaccard index is used as a similarity measure (Xu and Wunsch 2009:26). In the first run, we used single-linkage clustering to discover outliers. This led to the exclusion of one CCA action (`Tyrolean GenBank´) from further cluster analysis. We assigned this CCA action due to its uniqueness to a type of its own (´Hidden governmental action´). Using average-linkage clustering in the second run, we obtained five additional clusters of CCA-actions (cf. Fig. 2). This number of clusters was chosen based on Thorndike's elbow method – which indicated a four cluster solution – and comparing the interpretability of solutions ranging from four to seven clusters. During

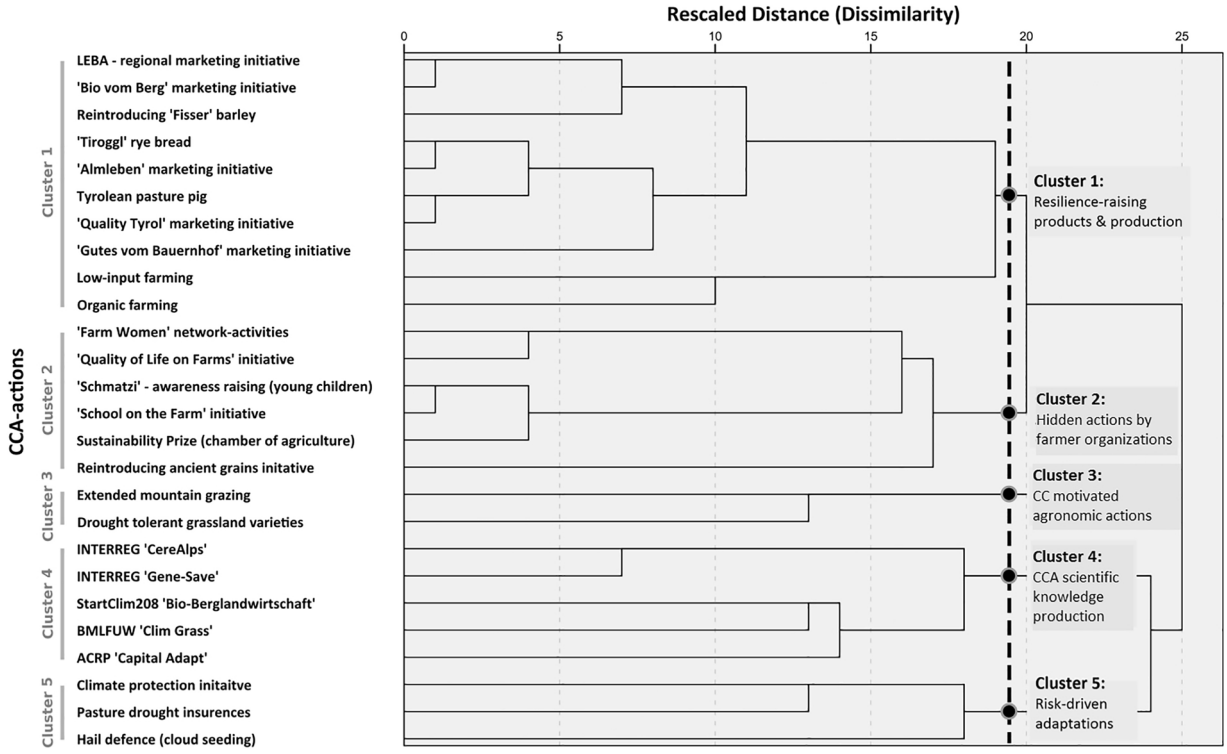

Fig. 2. Clusters and (dis-)similarities of CCA actions.

Table 2
Predominant categories of the six CCA action types in Tyrolean agriculture.

Type	Predominant categories	Example
1. Resilience-raising products and production	Actors are farmers or market players Economically motivated Hidden CCA Enhance resilience	"Bio vom Berg" - label for organic products
2. Hidden actions by farmer organizations	Initiated by farm organizations Varying motivations Hidden CCA	"School on the farm" – project
3. CC motivated agronomic actions	Climate change as motivation Agronomic actions Implementation on the field level	Extended mountain grazing
4. CCA scientific knowledge production	Temporary scientific projects Knowledge production about CCA	"ClimGrass" – project
5. Risk-driven adaptations	Mainly insurance companies as actors Risk management	Pasture drought insurance
6. Hidden governmental actions	Government actors High degree of formalization Hidden CCA, varying motivations	Tyrolean gene bank

this comparison the authors identified the five cluster solution as best compromise between detail, generalization and interpretability. Hence, the chosen two-step cluster approach led to a total of six different types of CCA actions in Tyrolean agriculture (cf. Table 2).

To evaluate the contribution of each of the seven dimensions for this final cluster solution we iteratively removed one of these dimensions from cluster analysis and compared the resulting clusters with the final ones. Appendix 2 provides a detailed description of this evaluation. The results indicate that dimensions 5 ("Degree of formalization") and 7 ("Spatial scale") have a rather limited relevance for the final cluster solution. In contrast, dimensions 1 ("Actors"), 2 ("Motivation"), 4 ("Focus of intervention") and 6 ("Adaptation output") proved to be highly relevant for classifying and characterizing Tyrolean CCA actions.

In the results section (5.2), we compare these six types with measures proposed in the Tyrolean climate strategy and discuss the resulting adaptation gaps.

5. Practical climate change adaptation in Tyrolean mountain agriculture

5.1. CCA types in Tyrolean mountain agriculture

As the outcome of our analysis of Tyrolean mountain agriculture, we identify six types of local CCA actions that cover a broad range of different actor-constellations, organizational approaches, thematic foci, spatial outreach, etc. Fig. 2 shows the results from the cluster analysis – five identified CCA types, excluding type 6 "Hidden governmental action" (cf. section 4.4).

Based on the seven dimensions (cf. Table 1), Table 2 presents the predominant categories differentiating the six types of CCA actions. In the following paragraphs, we provide a brief narrative of the main features of each type.

5.1.1. Type 1: Resilience-raising products and production

The highly competitive global agricultural market generates remarkable price pressure. This leads, on one hand, to efficiently produced low-priced commodities and, on the other hand, to high-quality niche products. The growing demand for local and organic food and consumers' willingness to pay extra for high-quality products with added ecological and/or animal welfare value reinforces the development of organic farming, which is considered as "CCA-friendly" and less harmful in terms of greenhouse gas emissions. These farm adaptations are rarely motivated by CC adaptation but mostly by economic, cultural and environmental/ecological motivations. Organic or other low-input farming styles contribute to CCA because they promote agroecological

resilience, biodiversity, healthy landscape management, and strong community knowledge processes (Borron, 2006:20). Organic farming has been demonstrated as a relatively cheap and practical option to address climate instability (Niggli et al., 2007:12). Furthermore, organic agriculture builds on the principle of closed loops, which reduces dependencies on fragile world market prices that are strongly affected by climate change (IPCC, 2014a).

Example "Bio vom Berg": This label for organic food products is owned by Tyrolean producers. The label identifies approximately 130 products, which are mostly produced and marketed in Tyrol. It communicates the origin of food to the consumers, who are willing to pay more for organic quality food produced by Tyrolean mountain farmers, operating in less-favored areas and confronted with steep slopes, difficult micro-climatic situations and other production handicaps.

5.1.2. Type 2: Hidden actions by farmer organizations

Tyrolean farmers are well self-organized in representative bodies that serve their interests and support common needs. In Austria, the Chamber of Agriculture, with several sub-organizations, is the main body of farmers' self-organization. It is responsible for agricultural extension, lobbying, consulting and supporting farmers in applying for compensation payments. The Chamber, however, also initiates and implements diverse projects to support farmers, e.g., in direct marketing and local food supply chains. Such projects, which are typically moderately formalized, are not motivated by climate change but by awareness raising for local quality products among consumers, income support for farmers and cost reduction for individual farmers. Nevertheless, these actions contribute to better adapted farming systems.

Example *"School on the farm" (Schule am Bauernhof)*: This project, initiated by the educational institute of the Chamber of Agriculture, provides children with insight into farm life and strengthens their agricultural knowledge. "School on the farm" raises future customers´ awareness of links between agriculture, consumption and environmental issues, which may lead to "CCA-friendly" purchasing decisions. Young people play an important role in climate change mitigation and adaptation and should also be integrated in these processes (Riede et al., 2017).

5.1.3. Type 3: CC motivated agronomic actions

Agriculture faces various challenges, and farmers are accustomed to adapting to manifold changing conditions (e.g., economic, weather-related, and social). Driven by experienced or observed climatic changes, farmers also directly implement agronomic adaptation actions on their farms.

Example "*Extended mountain grazing period"*: Due to climate change, an earlier onset of spring and an extension of the vegetation period occur, which enable farmers to leave their cattle on the pastures for a longer period. This extended grazing period means more feed and a shortened stall period, which usually implies lower costs and less labor for farmers but also improved animal welfare.

5.1.4. Type 4: CCA scientific knowledge production

Climate change adaptation has gained much attention from academic scholars during recent years, followed by a large amount of scientific output. Scientific research projects that focus on different adaptation aspects are also implemented in Tyrol and are usually motivated by knowledge production regarding climate change. Newly acquired knowledge from scientific projects should help to improve adaptation to CC.

Example "*ClimGrass"*: This research project investigates climate change impacts on grasslands with a technical simulation of weather extremes. Researchers monitor impacts on yields, fodder quality, plant stock, soil nutrients and soil water, and households. Concrete adaptation strategies for grassland management will be derived.

5.1.5. Type 5: Risk-driven adaptations

Insurance companies in particular have a highly risk-driven focus, and their services should help farmers to reduce diverse risks, most of them weather-related. Some risks can be connected to climate change (e.g., extreme weather events), and reducing these risks contributes to better adapted (farming) systems. Additionally, the Austrian insurance company for farmers (Österreichische Hagelversicherung) engages in awareness raising for climate change and advocates short supply chains to support their clients.

Example "*Insurance against drought damages in grasslands"*: Since 2015, the Austrian insurance for farmers ("Österreichische Hagelversicherung") protects farmers against the risk of damaged grasslands due to droughts. Droughts may lead to feed losses. Insured farmers receive financial compensation, which they can use to buy additional feed. This insurance thus increases the farm's adaptive capacity to droughts.

5.1.6. Type 6: Hidden governmental action

Governmental organizations initiate actions that can be triggered by manifold underlying motivations, such as the conservation of cultural heritage or biodiversity. Such actions are not motivated by climate change, but they may increase a sector´s adaptability, e.g., by the conservation of native plants that might be better adapted to weather extremes than new commercial varieties. When adaptation to climate change occurs as a side effect, we classify it as "hidden adaptation". The high degree of formalization of such actions results from governmental structures.

Example *"Tyrolean Genebank"* (Tiroler GenBank): For approximately 90 years, the Tyrolean government has been operating a gene bank for the collection, reproduction and conservation of ancient land plants. These old varieties preserve high genetic diversity, which increases the resilience and adaptability to climate change of mountain agriculture.

5.2. Comparison between identified CCA types and Tyrolean climate strategy

In order to identify further adaption needs it is necessary to confront official CCA policies with concrete local adaptation practices. A comparison between the *´Tyrolean climate mitigation and adaptation strategy´* and the identified six CCA types shows that only four out of the seven measures mentioned in the strategy partially overlap with the identified CCA practices (see Table 3). For the strategy measures ´research on emerging diseases and pests and optimization of adaptation and control strategies´, ´establishment and support for water-saving irrigation systems´ and ´improvement of animal health and welfare under changing climatic conditions´ no expression was found in local CCA practices. If analyzed from the opposite perspective, four adaptation types that were identified by the interviewees partially overlap with measures proposed in the Tyrolean strategy (´Resilience-raising products and production´, ´Hidden actions by farmer organizations, ´CC motivated agronomic actions´, ´CCA scientific knowledge production´), while "risk driven adaptations" and "hidden governmental actions" do not overlap with the Tyrolean climate strategy policy and even the overlapping types show major gaps (see grey fields in Table 3). Altogether there are only six out of 42 possible matches between the official strategy and the identified CCA types. The comparison revealed that top-down driven governmental policies have its limits in stimulating local adaption actions and vice versa.

6. Discussion

6.1. Discussion of adaptation types

Altogether, six different regional CCA types have been identified in Tyrolean mountain agriculture. The results reflect a wide range of already-implemented actions that contribute to CCA. According to our

Table 3
Overlaps between Tyrolean Climate Strategy and CCA action types (X = match, gaps in grey).

Local CCA types / Measures in the Tyrolean climate strategy	*1. Resilience-raising products and production*	*2. Hidden actions by farmer organizations*	*3. CC motivated agronomic actions*	*4. CCA scientific knowledge production*	*5. Risk-driven adaptations*	6. Hidden govern-mental actions
Research on emerging diseases and pests and optimization of adaptation and control strategies						
Recommendations for location-specific use of water-saving and heat-tolerant plants			X	X		
Establishment and support for water-saving irrigation systems						
Preservation of existing and revitalization of abandoned mountain pastures	X					
Assurance of soil fertility, structure and stability	X					
Improvement of animal health and welfare under changing climatic conditions						
Support of knowledge transfer and awareness raising		X		X		

typology introduced in Section 2 (on the basis of Grüneis et al., 2016), three out of six types can be clearly assigned to hidden adaptations ('resilience-raising products and production', 'hidden actions by farmer organizations' and 'hidden governmental actions'), while two types can be considered as multi-purpose adaptations ('risk driven adaptations' and 'CC motivated agronomic actions'), and only one type can be assigned to explicit CCA ('CCA scientific knowledge production'). Hence, the diverse CCA practices in Tyrolean mountain agriculture are often motivated by non-climatic issues (Wandel and Smit, 2000; Campos et al., 2014) such as ´productivity gain', 'support for farmers', 'awareness raising', 'environmental/ecologic improvement', 'resilience raising' and 'conservation of cultural heritage'. At first glance, some types seem to have no obvious connection to CCA. However, a closer look reveals that they actually seem to hold great potential for improving CCA, which is in line with the literature that suggests circular economies, organic farming, well-informed consumers or genetic variety as determinants that increase the adaptive capacities of the agricultural sector (Borron, 2006; Berkes, 2007; Darnhofer, 2010; Lengnick, 2015; Scialabba and Müller-Lindenlauf, 2010). This integrative approach may help to broaden the common understanding of climate change adaptation, which is still very much dominated by top-down and planned adaptation, i.e., first-generation adaptation (Boyd and Cornforth, 2013).

In contrast to other adaptation typologies (reviewed by Smit et al., 2000), the identified types from Tyrolean mountain agriculture are diverse and illustrate a broad picture of real-life local climate change adaptations. Next to typical categorizations, such as CCA significance (intent), adaptation output, spatial scale and actors (Tompkins et al., 2010, Smit and Skinner, 2002), our typology also considers underlying motivations, degree of formalization and the focus of intervention. The seven dimensions and 37 categories can be considered as a suitable analytic framework for a broad and hopefully more comprehensive investigation of local CCA practices in (mountain) agriculture.

The small overlap with measures from the ´Tyrolean climate mitigation and adaptation strategy´ can partly be explained by non-climatic motivations behind most of the identified CCA types. Moreover, the CCA types are principal different from measures from the strategy as the former were identified from agricultural practice and mostly contribute to CCA indirectly. Some of them are long- and well-established projects, mostly driven by non-climatic issues. In comparison with these CCA actions, top-down measures from the Tyrolean climate strategy directly address CCA effects. The strategy may serve as a guideline for other CCA related regional or local policies and provide measures which have mostly not been translated into concrete actions ready for implementation. A future revision of the Tyrolean climate strategy could focus more on the practicability of different CCA types and consider already implemented as well as hidden CCA actions. The differences between identified CCA types from practice and the official climate strategy also reflect the fact that there is little awareness among officials and policy-makers for adaptation needs in the Tyrolean mountain agriculture sector.

6.2. Picking the low-hanging fruit

Direct and purposefully planned CCA policies and actions are definitely important, but from a functional perspective, we argue that implicit climate change adaptations triggered by non-climatic drivers, which farmers may consider as more immediate pressures, should be dealt seriously and given equal attention. These multi-purpose and hidden adaptations can be considered as "low-hanging fruit", because they have already been successfully implemented by farmers and have only to be grabbed by local or national decision-makers to complement the CCA portfolio. Despite the fact that their climate change effectiveness is not easy to measure or assess, adaptations originating from "bottom up" have many immanent advantages. They already proved their social or political feasibility, are well accepted by their initiators and users, and thus gained a certain level of legitimacy. As local practices and local knowledge are relevant and valid (Adger et al., 2009), they can better combine immediate positive effects (e.g. on the farm economy) with the long-term effects of climate change adaptation. In addition, farmers usually have stronger motivation to react on present economic, political, cultural or environmental challenges than on future threats ahead. The implemented practices have demonstrated their flexibility and robustness and *"may garner easier political will or behavioural intent"* (Moser et al., 2010:22,029). In addition, they can serve as best practice examples for similar initiatives elsewhere (out-scaling); similar local initiatives can be coordinated and learn from each other (up-scaling). In a nutshell, such actions increase farm resilience, which may help agriculture in dealing with several challenges in addition to climate change.

For example, the farm womens´ network strengthens social and human capital which enhances farm resilience. This working group within the Chamber of Agriculture provides education, consultation and network activities among farmers and between farmers and consumers. Additional public support could encourage the farm women to extend their focus to climate change adaptation. The strong and renown network could help to establish credible CC-oriented education programs and spread information about CCA easily. Furthermore, in case of concrete damages (e.g. through floods) the network supports mutual self-organized help among farmers.

The comparison between the six CCA types and the Tyrolean climate mitigation and adaptation strategy shows that there is a gap between adaptation needs and efforts considered in policies and existing adaptation practices. Such an adaptation gap calls for re-focusing policies, strengthening local institutions and relying on already existing and functioning instruments such as flood protection planning systems or spatial planning tools. Instead of only re-inventing new climate change adaptation strategies, politics should also trust on and empower hidden and multi-purpose adaptation practices, which are already implemented, accepted and work well.

The results of our analysis highlight that the aim of any CCA policy is to empower local communities, acknowledge and support their adaptive capacities through providing resources and opportunities (such as time, space, access to social and institutional networks) and intangible appreciation. Even slight public support could intensify and multiply the impacts. This corresponds with the concept of multifunctionality (Van Huylenbroeck et al., 2007) that asks for an integrative perspective of productive, environmental, climate and other sustainability implications of agriculture and how to balance them by integrative policy intervention.

7. Conclusions

We propose an analytical framework for the identification of climate change adaptation practices that helps to identify six types of CCA practices in Tyrolean mountain agriculture. Although specific CCA practices are relevant only for Tyrolean mountain farming, the framework with its analytic dimensions and underlying categories can – after some adaptation to the context-specific conditions – also support similar analyses of CCA practices elsewhere, in other land use systems or even other sectors. The analytic framework is especially useful to

- show the full spectrum of adaptation practices within a region, including hidden adaptations that are motivated by other non-climate drivers;
- provide arguments for strengthening already existing CCA practices;
- identify adaptation gaps (e.g., in comparison to adaptation strategies);
- establish decision support for re-distributing public funds to adaptation gaps and low-hanging fruit of already successfully implemented adaptation practices with demonstrated feasibility, legitimacy, and local acceptance; and
- compare different regions, land use systems or sectors.

We do not argue that farmers will find a way to adapt to CC regardless and that no policy efforts are needed. But assuming that local actions are effective means for adaptation to climate change and are not implemented without policy support, we wish to show that next to top-down policies, local actions should also be supported. In addition to investments into new CCA initiatives to address adaptation gaps, support for existing practices, which already have met the feasibility and acceptability test, seems reasonable. In line with the concept of multifunctional agriculture, CCA policies – instead of 'interfering' with or substituting other policies - should rather scope all currently implemented measures that touch CCA, assess their effectiveness, identify gaps, and then implement horizontal support for 'hidden' actions (e.g. co-funding from CCA funds) and implement vertical support for very specific CCA actions that are needed to fill adaptation gaps. The case study also confirms agricultural sector determinants that increase adaptive capacities, such as diversity, circular economies, organic farming, human and social capital, or genetic variety (Berkes, 2007; Darnhofer, 2010; Jacobi et al., 2013; Lengnick, 2015; Scialabba and Müller-Lindenlauf, 2010). As diversity is a key factor in survival and adaptation (Campos et al., 2014), we should also consider different types of adaptation practices already successfully implemented on the local level.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2018.08.025.

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